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Paul Kistler

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSE(S)
Naval Facilities Engineering Service Center
Port Hueneme, CA 93043-4370

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Absorption chillers have a proven history of providing low-cost reliable cooling and should continue to do so in the future. Absorption chiller systems can provide significant energy savings for a particular application. To maximize savings, the various system arrangements should be evaluated; for example, single effect versus double effect, chiller versus chiller/heater, straight absorption chiller or the electric/absorption hybrid.

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Naval Facilities Engineering Service Center
Port Hueneme, California 93043-4370

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Advantages and Disadvantages of Using Absorption Chillers to Lower Utility Bills

Brief History of Absorption Chillers

The principles of absorption cooling were discovered around 1777. A patent was not issued, however, until 1860 to Ferdinand Carre. By the late nineteenth century, many large absorption chillers were being manufactured for process cooling in the chemical and petroleum industries. With the introduction of electrically-driven compressors and low-cost electricity, sales of absorption chillers dwindled until the 1930s when rising electrical rates revived the market. In 1936, research was begun on absorption cooling for air conditioning. By the 1960s, 40% of the chillers sold were absorption chillers. In the early 1970s, the gas shortage scare reduced sales of absorption chillers from 700,000 tons/year to less than 50,000 tons/year.

Absorption Chillers Today

Today, due to deregulation of the gas industry, gas exploration has been encouraged resulting in abundant supplies and relatively low prices forecast through the year 2050. Concern for the ozone layer is also driving a resurgence in absorption chiller sales since absorption chillers do not use chlorofluorocarbons (CFCs). Globally, 45% of all large chillers sold are absorption chillers and in the near future, those sales may increase to over 50%. In the United States, absorption chiller sales represent only 10% of the market; the overseas market is led by Japan, primarily due to the fact that fuel used to generate electricity must be imported, causing the Japanese government to encourage the use of natural gas wherever possible. As recently as 1989, no absorption chillers were manufactured in the United States; most were imported from Japan, but today, four manufacturers are now in business. These manufacturers (Trane, Carrier, York, and McQuay) have experienced sales increases of approximately 500% to 250,000 tons/year.

Recent Improvements to Absorption Chillers

Since the 1960s, several improvements have been made to absorption chillers, which include:

- Automatic purge systems eliminating the need for manual purging and lowering the potential for corrosion.

- Faster system response due to the use of electronic controls and concentration sensing.

- Electronic controls and sensors that make crystallization of the chiller far less likely than in the past.

- Lower water flow requirements - many machines use a standard flow of as little as 3.6 gpm/RT, and can be operated at 3 gpm/ton without significant de-rating. This raises the temperature change across the cooling tower, and allows an absorption machine to be installed as a replacement for a vapor compression machine with a minimum of chiller plant modifications.

• Absorption chillers can provide water temperatures as low as 38°F allowing for the use of reduced air flow and duct size in delivery systems, providing better dehumidification, reduced chilled water piping sizes, and pump requirements.

How Absorption Chillers Work

Although it may seem strange to put heat in the form of natural gas, or steam into a machine in order to get cold air out, it may make more sense to think of heat as energy, used to perform work such as removing heat from a building. Mechanical refrigeration systems work in this fashion. Energy, usually in the form of electricity, is used to remove heat from a building by driving a compressor.

An absorber, generator, pump, and recuperative heat exchanger replace the compressor in absorption refrigeration. Like mechanical refrigeration, the cycle "begins" when high-pressure liquid refrigerant (distilled water) from the condenser passes through a metering device (1) into the lower-pressure evaporator (2), as shown in Figure 1, and collects in the evaporator pan or sump. At this low pressure, a small portion of the refrigerant flashes to vapor. This process of vaporization cools the remaining liquid refrigerant. Similarly, the transfer of heat from the comparatively warm system water to the now cool refrigerant causes the latter to evaporate (2), and the resultant refrigerant vapor migrates to the lower-pressure absorber (3). There, it is "soaked up" by an absorbent lithium-bromide solution. This process not only creates a low-pressure area that draws a continuous flow of refrigerant vapor from the evaporator to the absorber, but also causes the vapor to condense (3) as it releases the heat of vaporization picked up in the evaporator. This heat, along with the heat of dilution produced as the refrigerant condensate mixes with the absorbent, is transferred to the cooling water and released in the cooling tower.

As the lithium-bromide absorbent soaks up the refrigerant it becomes more and more diluted, reducing its ability to absorb more refrigerant. In order to continue the cycle, the absorbent must be re-concentrated. This is accomplished by constantly pumping (4) dilute solution from the absorber to the generator (5), where the addition of heat (hot water, steam, or natural gas) boils the refrigerant from the absorbent. Once the refrigerant is removed, the re-concentrated lithium-bromide solution returns to the absorber, ready to resume the absorption process.

The refrigerant vapor which is boiled off in the generator goes back to the condenser (6), where it returns to its liquid state as the cooling water picks up the heat of vaporization. The refrigerant then returns to the expansion valve where it completes the cycle.

Classifications of Absorption Chillers

The primary differences between absorption chillers is the firing mechanism and whether they are single effect, double effect, or the latest development, which is triple effect.

Single effect machines have a single generator as previously described and require 15 psig steam or 180 - 270°F hot water. Single effect machines have COPs of 0.6 to 0.7. Double effect machines have a second generator (called the first stage generator) and condenser which operates with 100 to 150 psig steam or a 550 to 1,500° heat source. Refrigerant vapor is recovered from the first stage generator in the first stage condenser. The refrigerant vapor is then condensed at a higher temperature (in the first stage condenser) and the heat from this process is then used to vaporize additional refrigerant from a lower temperature, second stage generator. Double effect machines are more efficient than single effect machines with COPs around 1.04. A triple effect machine is now on the market which adds a third generator and condenser and is even more efficient with a COP of 1.5 to 1.6.

A steam-fired machine uses either steam or hot water as a heat source, and is the most common type of firing system for an absorption chiller. A direct-fired machine is the newest type and most commonly uses natural gas but may also use No. 2 oil, propane, or kerosene. It may also have a dual-fuel burner which allows for interruptible rates or as a backup.

Exhaust gas fired is the most expensive design. This type typically uses waste heat from a cogeneration plant but can use any heat source from 550 to 1,500°F such as from an incinerator.

A direct-fired or exhaust-fired machine can also supply hot water in lieu of, or in addition to cold water. This type of design may be referred to as a chiller/heater.

Why Use Absorption Cooling?

The primary advantage of absorption chillers is lower utility bills. Depending on rate structures and the difference in cost between natural gas and electricity, various strategies can be used to save energy costs. If natural gas costs are sufficiently low and electric rates high, all of the cooling load can be carried by an absorption chiller. If demand charges are high or there are high ratchets in the electrical rate structure, the peak loads can be cut using absorption cooling while the base load is carried by an electric chiller. Also, if a facility has a source of low grade heat currently going to waste, a single effect chiller may be ideal.

Although initial costs of absorption chillers can be $150.00 to $250.00/ton higher than an electric chiller, if the absorption chiller replaces a boiler, or if new electrical service must be

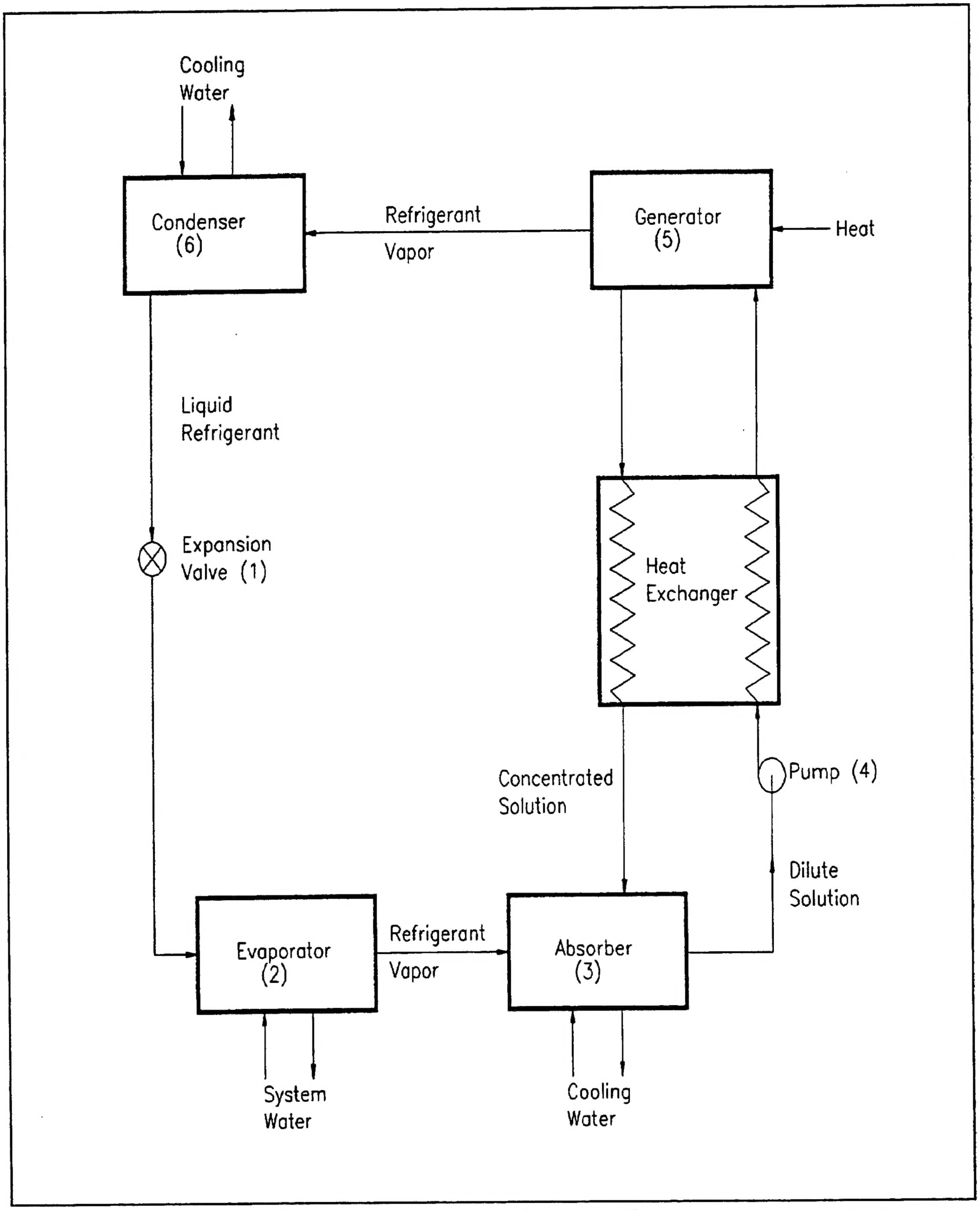

Figure 1. Absorption refrigeration cycle

provided for an electrical chiller, it may be more economical to go with the absorption chiller. Another incentive to use gas cooling may be the fact that electrical utilities prefer customers with large stable loads, and with deregulation, base rates may be going down for large facilities while demand charges go up.

Maintenance on absorption chillers is about the same or slightly higher compared to electric chillers running from $11 to $28/ton per year for a steam fired unit. A direct-fired unit will run $17 to $30/ton per year. Comparable electric chillers are $15 to $22/ton per year for a low pressure system and $20 to $27/ton per year for a high pressure system. If the absorption chiller is used to heat hot water, maintenance costs of a boiler and a chiller must be used for comparison. In this case, an absorption chiller would clearly come out ahead.

Other advantages to absorption chillers are no CFCs, and the lithium-bromide solution is non-toxic. Also, direct-fired, natural gas absorption chillers can cut sulfur dioxide emissions by 100%, nitrogen oxide by 68%, carbon dioxide by 57%, and particulates by 97% over oil-fired, peaking power plants and coal-fired, baseload power plants.

Past Problems With Absorption Chillers

The primary problems in the past have been crystallization and vacuum leaks. Crystallization occurs when the machine operates too close to the saturation temperature of the lithium bromide solution and the lithium bromide begins to precipitate out of the solution. While this will not damage the machine, it is a nuisance and usually requires application of external heat to get the lithium bromide back into the solution. Newer machines have electronic controls which prevent the chiller from operating at temperatures and concentrations which allow crystallization to occur. If the unit is operated properly, and maintained, crystallization is nearly a thing of the past.

Vacuum leaks are a serious problem adversely affecting the efficiency of the machine and causing corrosion in the unit. For this reason, points of entry for air, such as valves, must be maintained and repaired as necessary. Newer machines have automatic purges which help to eliminate the effects of vacuum leaks, but the purge tank has a manual valve which must be cycled weekly to remove non-condensable gases.

Other than these problems (which are infrequent on newer machines), absorption chillers are relatively trouble-free, partly due to the fact that there are only two moving parts, the purge, and the pump.

Disadvantages of Absorption Chillers

Two of the primary disadvantages of absorption chillers are their size and weight, and their requirement for larger cooling towers. Absorption chillers are larger and heavier than electric chillers of the same capacity. If they are used to replace both a boiler and a chiller, however, the size and weight of an absorption chiller/heater is less than that of a combined electric chiller and a boiler.

Absorption chillers require cooling tower capacities approximately 1/3 greater than electric chillers of the same size. An absorption chiller of the same size as an electric chiller can use the same cooling tower but its capacity and efficiency will be reduced.

Conclusions

Absorption chillers have a proven history of providing low-cost reliable cooling and should continue to do so in the future. Absorption chiller systems can provide significant energy savings for a particular application. To maximize savings, the various system arrangements should be evaluated; for example, single effect versus double effect, chiller versus chiller/heater, straight absorption chiller or the electric/absorption hybrid.

For more information on absorption cooling contact:

Mr. Paul Kistler

ESC 222
Energy Program Execution Branch

(805) 982-1387, DSN 551-1387, or
Internet: pkistle@nfesc.navy.mil.